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FERROELECTRIC LIQUID CRYSTAL DISPLAY ELEMENT
[Kyou yudensei ekishou hyouji soshi]

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Specification

1. Name of this Invention

FERROELECTRIC LIQUID CRYSTAL DISPLAY ELEMENT

2. Claims

Ferroelectric liquid crystal display element comprising a liquid crystal cell having ferroelectric liquid crystal layer between a pair of electrodes, wherein at least one separating wall is formed on one of electrodes of liquid crystal cell to divide the space in the liquid crystal cell into at least two sections, and each divided section is filled with ferroelectric liquid crystal having a different threshold voltage.

3. Detailed Explanation of this Invention

[Field of the Invention]

The present invention relates to a liquid crystal display element utilizing ferroelectric liquid, which is prepared by separating the space in the liquid crystal cell into at least two sections by forming at least one separating wall on one of electrodes of liquid crystal cell and makes each divided section filled with ferroelectric liquid crystal having a different threshold voltage so as to provide clear gradation gaps.

[Prior Art]

An art of displaying gradations of a liquid crystal display element is presently made available by an area gradation method (Pat. No. 62-71929, 62-145216, or the like) that varies the distance

between the picture element drive electrodes within the same picture element and controls the electric potential impressed between picture element drive electrodes and a time gradation method (Pat. NO. 62-205322, 62-17732, or the like) that varies the pulse width and pulse height of gradation signal voltage impressed to the liquid crystal layer.

The drawback of those gradation display methods is that the displayed gradation differences are not sharp. The gradation difference means the sharpness in the variation of transmitted light quantities among gradation levels [e.g., the relative quantity gap of transmitting light between the third gradation level and fourth gradation level (for example) if six gradation levels are provided.] Therefore, failure to show clear gradation gap is caused by the fact that the relative gap of transmitting light quantities is too small, and also, the changes in the transmitted light quantities are not drastic, but rather insignificant.

As a result, the conventional gradation display methods cannot clearly display middle gradations.

Another drawback is that the driving voltage waveform is too complex to apply simple designed driving circuits.

[Problems Solved by this Invention]

The object of this invention is to provide a ferroelectric liquid crystal element that can clearly display gradations with sharp gradation differences utilizing simple driving circuits.

[Method to Solve the Problems]

To achieve said object, this invention provides a ferroelectric liquid crystal display element comprising a liquid crystal cell having ferroelectric liquid crystal layer between a pair of electrodes, wherein at least one separating wall is formed on one of electrodes of liquid crystal cell to divide the space in the liquid crystal cell into at least two sections, and each divided section is filled with ferroelectric liquid crystal having a different threshold voltage.

[Operation]

Since one picture element is divided into at least two partial picture elements by a separating wall, and the threshold voltage of ferroelectric liquid crystal constituting each part of picture element is made different, each partial picture element can be separately turned on or off by varying the impressing voltage in at least three levels, subsequently allowing one picture element to display a plurality of clear gradations.

[Operational Examples]

Figures 1 and 2 are diagrams showing an example of liquid crystal cell configuring the ferroelectric liquid crystal display element of the present invention. In the figures, the reference numeral **1** denotes a pair of transparent substrates made of glass or the like. One of those substrates **1** (lower substrate in Fig. 1) has stripes of scan electrodes **2**… made of indium tin oxide (ITO) or the

like. Those scan electrodes **2**… are arranged to allow their longitudinal directions horizontally parallel as shown in Fig. 1.

Furthermore, the other transparent substrate **1** (upper substrate in Fig. 1) has stripes of signal electrodes **3**… made of the same kind of material (i.e., ITO or the like). Those signal electrodes **3**… are arranged to orient their longitudinal directions, vertically crossing the longitudinal directions of scan electrodes **2**.

In addition, orientation films (e.g., SiO slanted vapor deposited film, polyamide rubbing film, or the like; not shown in the figure) are formed on those scan electrodes **2**… and signal electrodes **3**…

Moreover, one continuous separating wall **4** is provided between the scan electrode **2** and signal electrode **3**, being arranged parallel to the thickness direction of the liquid crystal cells. As shown in Fig. 1, the upper end face of this wall **1** is adhered to the orientation film on the signal electrodes **3**, and its lower end face is adhered to the orientation films formed on the scan electrodes. In addition, as shown in Fig. 2 exhibiting the plane configuration of the device, the separating wall **4** is positioned on the approximate center line of each signal electrode **3**… and connected to the adjacent wall **4** at one end of signal electrode **3**…, perpendicularly bridging from one end of electrode **3** to the other end of adjacent electrode **3** on the same side. Also, the ends of both sides of this separating wall **4** contacts the sealing agent (not shown in the figure)

surrounding the liquid crystal cell. Therefore, this one continuous separating wall **4** divides the space in the liquid crystal cell into two equal plane areas.

This separating wall **4** is made of a non-conductive material (e.g., silica, aluminum, or the like) by a combination method of conventional thin film forming technique and photolithography or the like.

One (A) of spaces formed by the separation wall **4** halving said area is filled with the first ferroelectric liquid crystal (b) to construct a liquid crystal cell. Also, in this example, the threshold voltage $\mathbf{V_A}$ is made greater than the threshold voltage $\mathbf{V_B}$ of the second ferroelectric liquid crystal (b).

When the liquid crystal cell is configured in this manner, one picture element formed by one scan electrode **2** crossing one signal electrode **3** is also divided into partial picture elements $\mathbf{P_A}$, $\mathbf{P_B}$ of equal areas divided by the separating wall **4**, thereby allowing the first and second partial picture elements $\mathbf{P_A}$ and $\mathbf{P_B}$ to respectively contain the first and second ferroelectric liquid crystals (a) and (b).

When an impression voltage $\mathbf{V_{OP}}$ is impressed between the scan electrode **2** and signal electrode **3** configured as described above, if the voltage $\mathbf{V_{OP}}$ is smaller than the second threshold voltage $\mathbf{V_B}$ of ferroelectric liquid crystal (b), both the partial picture elements $\mathbf{P_A}$, $\mathbf{P_B}$ become OFF, subsequently resulting in the OFF state of this

whole picture element. On the other hand, when the impression voltage $\mathbf{V_{OP}}$ is arranged greater than the second threshold voltage $\mathbf{V_B}$ of ferroelectric liquid crystal (b) and smaller than the threshold voltage $\mathbf{V_A}$ of ferroelectric liquid crystal (a), although the first partial picture element $\mathbf{P_A}$, remains in the OFF state, the second partial picture element $\mathbf{P_B}$ becomes ON, thereby causing a half of picture element to become the ON state. Furthermore, if the impression voltage $\mathbf{V_{OP}}$ is arranged greater than the first threshold voltage $\mathbf{V_A}$ of ferroelectric liquid crystal (a), both the partial picture elements $\mathbf{P_A}$, $\mathbf{P_B}$ become ON to provide the ON state of one picture element. Therefore, the liquid crystal cell in this example can provide three levels of gradation display by simply making the impressing voltage $\mathbf{V_{OP}}$ higher or lower.

Figure 3 is a graph showing the optical response characteristic of one picture element during this operation. As shown in this graph, the variation of light passing ratio at the time of transferring from the first gradation level to the second gradation level, which utilizes the threshold value voltage of the ferroelectric liquid crystal, is extremely steep to form approximate steps. Hence, the gradation level gap clearly appears. Also, gradation display is provided by increasing or decreasing the impressing voltage, drive circuits can be simpler.

In addition, since this liquid crystal cell sealing two kinds of ferroelectric liquid crystals allows simultaneous two injections of

liquid crystal fed from two inlets, the liquid crystal injection time can be shortened. Moreover, as the height of separating wall **4** sets the cell gap of the liquid crystal cells, a conventionally used spacer for regulating the cell gap can be eliminated.

Figure 4 is a diagram of the disposition of a plurality (three in the figure) separating walls **4**... In this example, the inside of liquid crystal cell is divided into four spaces A, B, C, and D in which four different ferroelectric liquid crystals, each having a different threshold voltage. Also, one picture element is divided into four approx. equal sections to allow five levels of gradation display.

Note that the method describe above can be combined with a plural electrode method that divides one signal electrode into several sections.

Figure 5 is a diagram showing an example of technique combining the method described above and plural electrode method. In the figure, one signal electrode **3** is divided into three sections along the longitudinal direction, setting the area ratio of divided electrode sections **3a**, **3b**, and **3c** to 1 : 3 : 5. In addition, one piece of separating wall **4** is provided, being arranged on the approx. center line of the scan electrode **2** along the longitudinal direction of the electrode **2**. Therefore, in this example as shown in Fig. 6, one picture element is divided into six partial picture elements **5**..., wherein the first ferroelectric liquid crystal (a) exists in three of

those elements, and the second ferroelectric liquid crystal (b) exists in the remaining three elements. Subsequently, by varying the impressing voltage V_{OP} in three levels as explained above and combining the ON/OFF of the signal transmitted to the partial electrodes **3a**, **3b**, and **3c**, a total of 19 levels of gradations can be displayed.

[Effectiveness of this Invention]

As explained above, this invention provides the following ferroelectric liquid crystal display element comprising a liquid crystal cell having ferroelectric liquid crystal layer between a pair of electrodes, prepared by at least one separating wall is formed on one of electrodes of liquid crystal cell to divide the space in the liquid crystal cell into at least two sections, and each divided section is filled with ferroelectric liquid crystal having a different threshold voltage. Therefore, the provided element can distinctly display gradations with clear gradation differences. Moreover, the drive circuit can be simply designed. Furthermore, the production method of said display element can reduce the time for injecting ferroelectric liquid crystal into a cell, while being able to utilize the separation wall as a spacer for regulating the cell gap.

4. Simple Explanation of Drawings

Figures 1 and 2 are diagrams showing an example of liquid crystal cell, wherein Fig. 1 is a cross-sectional diagram of the

cell, and Fig. 2 is a diagram explaining the location of the separating wall in the cell.

Figure 3 is a graph showing the optical response characteristic of one picture element when displaying gradations.

Figure 4 is a diagram explaining another example of separation wall location.

Figures 5 and 6 are diagrams showing applications of this invention, wherein Fig. 5 is a diagram explaining the electrode division state and location of separating wall, and Fig. 6 is a diagram explaining the dividing condition of one picture element in this application.

2···Scan electrode;

3···Signal electrode;

4···Separation wall;

A, B···Space;

a···First ferroelectric liquid crystal;

b···Second ferroelectric liquid crystal.

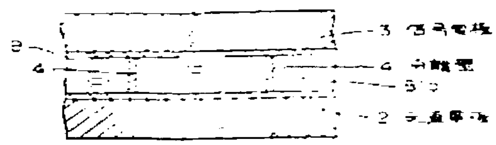

Figure 1

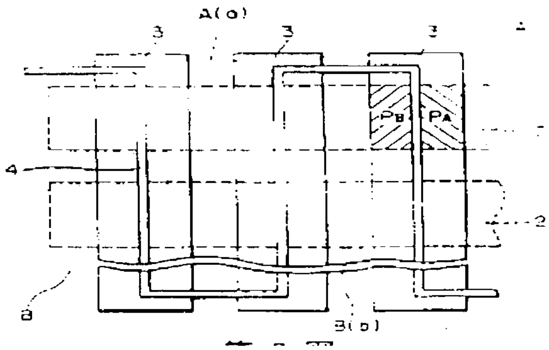

Figure 2

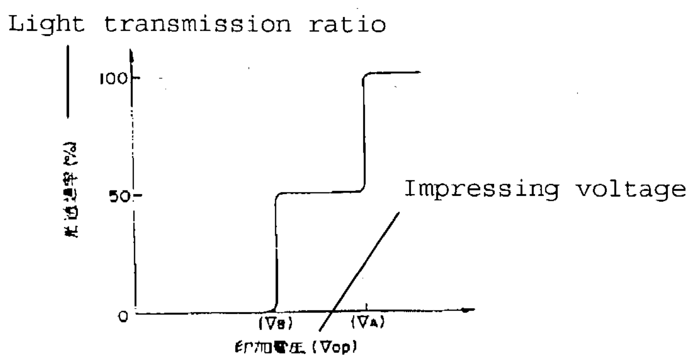

Figure 3

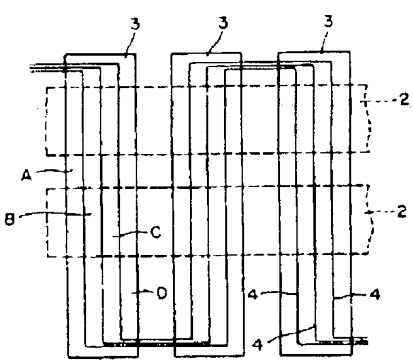

Figure 4

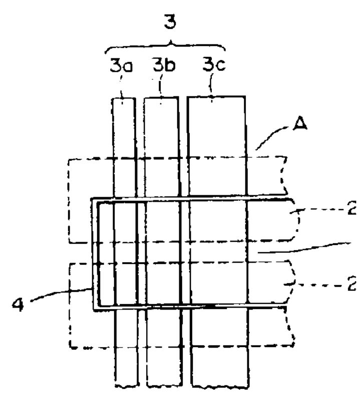

Figure 5

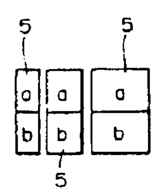

Figure 6